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HELICOPTER NOISE

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Author: John W. Leverton
J.W. Leverton.

E.J. Richards
E.J. Richards
Director, Institute of
Sound and Vibration Research,
Southampton.

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RESEARCH PERSONNEL:

Supervisor	Professor E.J. Richards
Research Staff	J.W. Leverton (Research Fellow)
Associate	Dr. J.P. Jones
Research Assistant	Miss M.S. Patrick

CONTENTS

1. INTRODUCTION

This report summarises the first six months of the work carried out in connection with the N.A.S.A. helicopter rotor noise contract.

The N.A.S.A. programme contains the following :-

(1) A theoretical study of rotor noise, in steady and unsteady conditions.

(2) An experimental investigation of the noise produced by the I.S.V.R. model hover rig.

(3) Measurements of the noise produced by real helicopters and a comparison with theory and the results from the rig tests.

(4) Investigation into transient effects such as 'blade slap'.

(5) A narrow band analysis study of the noise from ancillary equipment, gear boxes, etc., in helicopters and hovercraft.

Note: Because of the amount of data already available on the topic of blade slap, (1,2,3), this is being treated as a separate subject.

2. SCOPE OF INITIAL INVESTIGATIONS

The initial work has been limited to the study of rotor noise under steady conditions and Blade Slap.

To date investigation has been mainly directed towards obtaining the experimental data (for sections 2 & 3) and determining the noise characteristics of the I.S.V.R's hover rig over its full range of operating conditions. This work is aimed at obtaining a basic understanding of the rotor noise problem and determining the noise 'trends' associated with the various rotor parameters.

The present programme is designed to give the relationships between the noise and operating conditions with the object of clarifying the nature of the sources. Although determination of the absolute amplitude of the rotor noise is very desirable at this stage of the work it is considered only of secondary importance.

3. TEST FACILITIES

3.1. HOVER RIG AND ROTOR BLADES

The University's hover rig is being used for the investigation into rotor noise. The rig, which was designed to take blades of about 9 ft. diameter, is driven by an electric motor via a Ward-Leonard Set and the operating R.P.M. is measured electronically.

For these preliminary investigation the rig was fitted with a three bladed rotor head having 'flapping' hinges, but no lead/lag arrangement. The blades are of a rectangular plan form without twist, having a radius of 54 inches. The blades have an N.A.C.A. 0012 aerofoil section with a 4 inch chord. The main spar and leading edge are made of aluminium whilst the trailing edge is formed from expanded Polystyrene. The blades are essentially square tipped, with the tips being made of wood.

The pitch of the blades can be set at any angle between $\pm 15^{o}$ in $\frac{1}{2}^{o}$ increments by means of a screw arrangement at the cuff. Because of the absence of twist the blades on the hover rig can be set and run at 'true' zero pitch, a condition which is not possible with real helicopter blades.

The maximum R.P.M. of the rotor is in the order of 1200 R.P.M., but for this work, where it is run for long periods, it has not been run above 1000 R.P.M., which is equivalent to a tip speed of 470 ft/sec.

Although only the three bladed rotor head has been used, rotor heads are available which will accommodate 1 to 4 blades. It is likely that these other rotor heads will be used during the next stage of work.

3.2. LOCATION OF THE HOVER RIG

The hover rig is situated in the Structures Laboratory which is semi-reverberant and contains a considerable number of other rigs and equipment. Although some of these pieces of equipment are in close proximity to the hover rig, they do appear to impose any severe acoustic limitations.

Noise from the Ward-Leonard set, which is situated only 10 ft. from the rig, has been reduced to an acceptable level by lagging it with foam rubber.

3.3. BLADE TRACK

The blades are 'tracked' at the beginning of each series of tests and after every replacement of the blades. Tracking, at zero pitch, is carried out in two stages. First, the 'flapping hinges' are adjusted so that statically all the blade tips are in the same plane. The rotor is then run at 300 R.P.M. and the 'track' checked by means of a stroboscopic light. During these tests the track has been checked over the full range of R.P.M's. and pitch settings and in all cases it has been found to be excellent.

3.4. RECORDING AND ANALYSIS EQUIPMENT

Standard Bruel & Kjaer equipment has been used for obtaining the necessary noise measurement. All the data is recorded on tape; up to now all the recordings have been Direct (A.M.) Recordings.

Analysis is performed by making a 5 ft. long tape loop of each condition and playing it back through the necessary analysing equipment.

The rotational or discrete noise results have been obtained from narrow band traces whilst the vortex noise has been obtained by using broadband and octave filters.

The narrow band traces have been produced by using a Muirhead Automatic Wave Analyser (K-100-A) with a 1.5% bandwidth. Although the bandwidth of this analyser is small enough at the low frequencies (below 100 cps) to allow the lower rotational harmonics to be determined accurately, at the higher frequencies it becomes extremely difficult to separate the higher harmonics because of the increase in bandwidth with frequency.

For the above reason a detailed study has been carried out of all the narrow band analysers available in the U.K. This has been time consuming, but it is considered that much more information could be obtained if a more suitable analyser could be used. Two suitable analysers have been located and these will be tested shortly. It is hoped that one of these will be purchased before the end of the year and be available for the rotor noise investigation.

The broad band noise has been studied by two methods. A cut-off filter was introduced in the circuit so that only the noise above 250 cps was recorded. Secondly, the vortex noise has been obtained by summing the levels in the octave bands with centre frequencies between 250 and 8000 cps. These results are, of course, practically identical.

Other techniques are being investigated which will enable the modulation depth of the broad band noise to be determined accurately and the variation in the levels of the individual rotational harmonics to be measured over the complete speed range rather than at present at selected R.P.M's.

4. EXPERIMENTAL WORK

4.1. LABORATORY TESTS

A series of measurements have been made of the noise generated by the hover rig over a range of R.P.M's. and pitch settings using a three bladded rotor. The conditions were :-

Rotor R.P.M.	200	-	1000
Equivalent Tip Speed	94	-	470 ft/sec.
Pitch Setting	0	-	12^{o}

At the larger pitch settings it was not possible to attain the higher speeds, e.g. at 10^{o} pitch, the maximum R.P.M. obtainable was 800 - the limitation being imposed by the power available from the drive motor.

4.2. FULL SCALE TESTS

Rotational (Ordered Tones) and Vortex (Broadband) noise levels have been measured by Westland Aircraft Ltd. (Fairey Aviation Division) and these are reported in Reference 4. These results were obtained from a three bladed rotor fitted with Wessex blades. This work is being continued and in the present series of tests all the types of blades available in Britain are being used. In addition, measurements are being made of noise produced by a single rotor blade. The results of these tests will be made available to the I.S.V.R. when the analysis is complete.

The original series of measurements (Reference 4) is being used to obtain a direct comparison between model and full scale tests.

4.3. FLIGHT TESTS

Westland Aircraft Ltd. (Yeovil Division) have made available noise measurements obtained from their Wessex helicopter (4 bladed single rotor) in flight. These results will be used for a study of the differences between the rotor noise when the blades are fitted to a helicopter and when they are run on a whirl tower. These results will also be used as a basis of a study into the changes of the noise spectra associated with distance, altitude, etc.

5. THEORETICAL APPROACH

On the theoretical side, a review of the present state of the 'propeller' and 'rotor noise theory' is being carried out. This seems to indicate that although the determination of the broad band vortex noise is likely to lead to fairly good results, accurate estimation of the discrete frequencies is going to be extremely difficult.

Sikorsky Aircraft has recently developed a detailed programme for calculating the levels of the discrete frequency noise under any condition. They have agreed to supply the I.S.V.R. with a copy of this programme, with the result that it will be used as a basis for our theoretical study of this type of noise. Preliminary results suggest that the harmonic fall-off of the noise of the I.S.V.R. hover rig is more consistent with this theory than the full scale measurements. This could be due to the wind and turbulence effects which are encountered during external measurements.

6. BLADE SLAP

There has not been any direct work in connection with this topic during the period covered by this report. Considerable information on the possibilities of blade/vortex has, however, been obtained from the vortex flow visualisation investigation (Reference 5) which was supervised by Dr. J.P. Jones.

The following two programmes have been formulated as part of the blade slap investigation and these will be carried out in the near future.

(1) A rotor blade will be passed through an air jet in such a manner that the combined velocity is greater than the speed of sound. This will, of course, be carried out on a full size whirl tower where the tip speeds are very much greater than those obtainable on the I.S.V.R. hover rig.

(2) Westland Aircraft Ltd. (Yeovil Division) are going to fly their Wessex (single rotor - 4 blades) and Sycamore (single rotor - 3 blades) helicopters in blade slap conditions. These machines will be fitted with an azimuth maker and simultaneous recording of the noise and blade position will be made. It is hoped that this will lead to the determination of the position of the blades when 'bang' or 'slap' occurs.

7. PRELIMINARY RESULTS

7.1. BROAD BAND (VORTEX) NOISE

The broadband analysis of the measurements is now complete, but the data has not been fully correlated.

Although this analysis is incomplete, the following results have been determined.

(1) For rotor R.P.M's. above 400 (tip speeds of 120 ft/sec) and pitch setting above 2^o, the S.P.L. is proportional to V^6 and $\alpha^{1.66}$ where V is the tip speed and α the pitch setting.

This is in agreement with the parameters obtained from the full scale tests (reference 4).

(2) For lower rotor R.P.M's. the noise varies from these laws; for example, at very low speeds the S.P.L. appears to be proportional to V^4.

7.2. DISCRETE FREQUENCY (ROTATIONAL) NOISE

This has not been analysed in any great detail, but the following trends are clear:

(1) The fall-off in level of successive harmonics is more rapid on the I.S.V.R. rig than encountered on the full scale or flight tests. Preliminary indications are that this type of harmonic fall-off is more consistent with the theory than the full scale measurements. This seems to suggest that local turbulence and wind (which is encountered in external tests) may have a significant effect on the discrete frequency noise.

(2) The variations of the S.P.L. of individual harmonics with the various blade parameters tend to be in general in agreement with those obtained from the full scale tests, but this data has not yet been fully correlated.

8. FUTURE WORK

The analysis of the information obtained from the preliminary tests will be completed before deciding on a detailed programme for future work. At present it is planned to study vortex or broad band noise before tackling the rotational noise problem.

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